Renewable and Sustainable Energy Reviews 24 (2013) 445–453

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The impacts of transport energy consumption, foreign direct investment and income on CO_2 emissions in ASEAN-5 economies

V.G.R. Chandran [a,*], Chor Foon Tang [b,1]

[a] Department of Development Studies, Faculty of Economics and Administration, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Department of Economics, Faculty of Economics and Administration, University of Malaya, 50630 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 24 November 2012
Received in revised form
14 March 2013
Accepted 18 March 2013
Available online 24 April 2013

Keywords:
GDP
FDI
Transport energy consumption
ASEAN

ABSTRACT

In this study, we incorporate new variables and assess the impact of transportation sector's energy consumption and foreign direct investment on CO_2 emissions for ASEAN-5 economies using the cointegration and Granger causality methods. This study also attempts to validate the Environmental Kuznets Curve (EKC) hypothesis. Our results reveal that the CO_2 emissions and their determinants are co-integrated only in Indonesia, Malaysia and Thailand. The long-run elasticity estimation suggests that income and transport energy consumption significantly influence CO_2 emissions whereas FDI is not significant. Economic growth plays a greater role in contributing to CO_2 emission in ASEAN-5. Nonetheless, we find that the inverted U-shape EKC hypothesis is not applicable to the ASEAN-5 economies, especially in Indonesia, Malaysia and Thailand. In the long run, the bi-directional causality between economic growth and CO_2 emissions is detected in Indonesia and Thailand, while we find unidirectional causality running from GDP to CO_2 emissions in Malaysia. We also observe bi-directional causality between transport energy consumption, FDI and CO_2 emissions in Thailand and Malaysia. As an immediate policy option, controlling energy consumption in transportation sector may result in a significant reduction in CO_2 emissions. However, this may slow the process of economic growth in Malaysia and Indonesia. Alternatively, we suggest policymakers to place more emphasis on energy efficient transportation system and policies to minimise fossil fuel consumption. Thus, the quality of environment can be improved with less deleterious impact on economic growth.
© 2013 Elsevier Ltd. All rights reserved.

Contents

1. Introduction

Increasing concerns about the environment have turned the scholars as well as policymakers' attention to identify the determinants of environmental pollutions and the direction of their

* Corresponding author. Tel.: +6017 6843705.
E-mail addresses: vgrchan@gmail.com (V.G.R. Chandran), tcfoon@yahoo.com (C.F. Tang).
[1] Tel.: +6012 4232254.

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.03.054

influence [1–3]. Among the most important variables that are associated with environmental degradation are energy consumption and economic development goals that a country pursues at the expense of the environment. Although this has translated into the identification of the determinants of environmental pollutions, the majority of the studies limit their analysis by only linking the total energy consumption and economic growth to environmental pollution, particularly CO_2 emissions. Energy consumption and growth alone may not explain CO_2 emissions [4,5]. However, it is also common that in linking energy consumption to CO_2 emissions, most of the previous studies stress on the type of energy used (usually coal and electricity) and investigate the relationship between coal and electricity on CO_2 emissions ([6–10]). The role of foreign direct investment (FDI) and the transport sector's energy consumption are less explored especially in ASEAN although FDI and emerging transportation sectors increasingly play an important role. Indeed, the rising FDI flow in developing countries raises an important question as to whether it has any environmental consequence [11]. Similarly, Lean and Smyth [12] have strongly proposed that future researches should examine road transport energy use and pollution emissions. The transport sector contributes to the growing share of emissions [13]. Despite this, due to the economic growth and fossil fuel combustion, pollution emissions are progressively increasing in ASEAN-5 ([12]), requiring urgent attention by scholars and policymakers to identify their sources beyond the scope of total energy use.

In this study, we attempt to validate the Environmental Kuznets Curve (EKC) hypothesis for ASEAN-5 where past literatures, by means of panel data analysis, have provided mixed and inconclusive evidences for each of the countries [6,12,14,15]. Our approach in this study involves a time series analysis, cointegration and Granger causality tests of an individual country as the case study, to avoid some of the drawbacks in panel data analysis.[2] The country-specific analysis will enable us to capture and account for the complexities of the economic environment and histories of energy development in the respective countries, of which panel analysis is unable to capture. Furthermore, country-specific analysis such as ours is needed to provide consistent results [21]. In addition, our study focuses on two neglected or less researched aspects of the previous studies that examined the determinants of CO_2 emissions in ASEAN-5. First, previous studies are short on analysing the complexity of FDI and CO_2 emissions relationships and causality leading to less insight on the pollution haven hypothesis although ASEAN-5 is active in attracting FDIs. Conventional wisdom may suggest that with relaxed environmental standards in developing countries, FDI may promote CO_2 emissions at large [22]. However, the role of FDI can also be in reverse when FDI introduces low carbon technology that in return reduces the CO_2 emissions as a whole or when FDI inflows concentrate on service sectors. In a similar note, Zeng and Eastin [11] found that at large, FDI inflows in less-developing countries promote better environmental awareness.

Second, in previous literatures, the role of transport sector in determining the CO_2 emissions is not available despite its growing importance in Asia [13,23]. In this case, apart from examining the CO_2 emissions by source of energy (e.g. coal, oil, gas and others), we take a sectoral approach to identify the determinants of CO_2 emissions. In 2009, coal, oil and gas contributed 43%, 36.7% and 20% of the world's CO_2 emissions, respectively [24]. Fossil fuel combustion has been the main contributor of CO_2 emissions. Among the sectors, the transport sector is the main sector in contributing to CO_2 emissions from the fuel combustion. Decomposing the sectoral source of CO_2 emissions indicates that electricity and heating production contribute 40.8% of the total world CO_2 emissions, followed by transportation (22.6%), manufacturing industries and construction (20%), other energy industry usage (5%) and other sectors (11.4%) [24]. Indeed, given the fact that on average, ASEAN-5 transport energy consumption comprises about 22% of the total energy, it is vital to understand the role of transport sectors in determining the CO_2 emissions. Understanding the effects of transportation energy consumption on CO_2 emissions at national level allows us to establish a more specific and operational policy guide to policymakers in the transport sectors to derive appropriate transportation policies.

2. The ASEAN context

ASEAN-5, namely Malaysia, Indonesia, Singapore, the Philippines and Thailand have progressed economically well compared to other members of ASEAN. Among the ASEAN countries (excluding Brunei), in terms of per capita income in 2008, Singapore (USD 39,991) ranked the highest followed by Malaysia (USD 8032), Thailand (USD 4103), Indonesia (USD 2245) and the Philippines (USD 1840). The average GDP growth of ASEAN-5 between 2004 and 2009 was 5.9% with Singapore and Indonesia recording over 5% growth rates. The continuous growth of the ASEAN-5, specifically for Singapore and Malaysia compared to the rest, poses an interesting question among policymakers. Have Singapore and Malaysia experienced the Kuznets effects whereby they have reached a certain income threshold to reverse the effect of growth on CO_2 emissions? Similarly, the increasing per capita income may also significantly contribute to environmental pollution. Therefore, validating and testing this hypothesis is necessary given the impressive growth rate of these countries in the past. ASEAN energy demand growth, from 2005 to 2030, is expected to be higher at an average annual rate of 4% than the world average of 1.8% [25]. In fact, a higher fossil fuel use has significantly proved to be a challenge among policymakers especially in managing the issues of climate change. CO_2 emission is expected to increase by 5.1% annually as a result of primary energy consumption. Although the CO_2 emission is not high in relation to China, the United States and India, concerns emerged among policymakers on the steadily increasing CO_2 emission from fuel combustion and on issues of climate change. In fact, in the past, between 1995 and 2004, CO_2 emission increased at an average annual rate of 5.6% [26]. Indeed, ASEAN's position in taking a lead role in reducing the emissions footprint warrants the understanding of the sources of emissions and their causality. For instance, the ASEAN charter and the roadmap of ASEAN Community 2009–2015 have clearly established plans to pursue sustainable development goals.

Similarly, with the exception of Singapore, the growth in road transport energy consumption has been increasing in ASEAN-5. The average annual growth of road transport sectors energy consumption in the periods of 1971–2008 was the highest in Malaysia (6.7%), Thailand (6.6%) and Indonesia (6.3%).[3] In Malaysia, for instance, the availability of extended financial supports with favourable interest and subsidised oil price has increased the number of vehicle ownership and consequently resulted in an

[2] Solow [16] and Athukorala and Sen [17] suggested that due to the different nature of economic structure, income and also demographic reasons panel data may not be suitable. Indeed, due to different data quality across countries, estimations using cross-sectional and panel data may not yield robust results [18]. Robertson and Symons [19] and Pesaran and Smith [20] based on Monte Carlo experiments, indicated that when heterogeneous aspects exist in a panel model with a small cross-section (N) dimension as the case of our study ($N=5$), the estimation results are likely to be biased.

[3] Singapore and the Philippines recorded 4.5% and 2.7%, respectively.

Table 1
Road transport energy consumption, 2008.

Country	Total energy consumption (Mtoe)	Road transport energy consumption in total energy consumption (%)	Total oil consumption (Mtoe)	Road transport energy consumption in total oil consumption (%)
Malaysia	69.2	20.40	27.1	52.09
Philippines	27.0	25.46	12.3	55.82
Singapore	59.5	4.02	52.0	4.60
Thailand	95.9	18.38	44.2	39.91
Indonesia	123.3	19.08	58.7	40.08

increase in the energy demand for these sectors.[4] In addition, for the periods of 1960–2002, the average annual growth of vehicle ownership per 1000 population was 6.7% in Malaysia, 6.4% in Indonesia and 8.7% in Thailand [27]. This translates into a higher demand in energy consumption and only by shifting away from fuel oil consumption can it significantly reduce emissions. In 2008, road transport energy consumption in total energy consumption was 20% in Malaysia, 25% in the Philippines, 18% in Thailand, 19% in Indonesia and 4% in Singapore. Likewise, the road transport energy consumption in fossil fuel (oil) was approximately 50% in Malaysia and the Philippines and 40% in Thailand and Indonesia while Singapore recorded the lowest rate at 5% (see Table 1). Given the high proportion of fossil fuel consumption in ASEAN, at least in the 4 countries, the inclusion of road transport sectors energy consumption to address the climate change issues is essential. In fact, Timilsina and Shrestha [23] argued that ignoring transport sectors may not provide a holistic picture to address climate change and to formulate effective mitigation policies. However, it is important first to establish if there is any interrelationship between road transport energy consumption and CO_2 emissions before one can conclude the need for any mitigation policies.

The pollution haven hypothesis received considerable attention in developing countries ([28–30]) but little is yet known with regards to ASEAN except for a few studies[5] ([31–33]). ASEAN, at large, takes FDI-led growth strategies by attracting a significant amount of FDI inflows to increase its investment to propel their economic growth. Significantly, liberalisation efforts of each individual country have been long on-going and ASEAN as a whole has become one of the leading regions among the developing countries in attracting FDI. In particular, ASEAN-5 had in the past, managed to attract large amounts of FDI with Singapore leading the league. The total FDI inflows in ASEAN-10[6], between the years 1990 and 2009, amounted to nearly USD 602,529 million, and ASEAN-5 accounted for nearly 89% of the inflows. Specifically, Singapore attracted nearly 44% of the total inflows while Malaysia and Thailand accounted for 15% and 17%, respectively. While the benefits of outward orientation strategies are numerous, however, it comes with a cost, particularly on the environment. Besides, FDI inflows that significantly foster industrialisation have increased concerns on sustainable development in ASEAN [34]. Given the significant amount of capital inflows in ASEAN-5, it is vital to examine the effects of these capital inflows on environmental pollution. Nevertheless, given the fact that different sectoral composition of FDI inflows exist in each of these countries, it is rather interesting to observe how the long-run influence of FDI on CO_2 emissions differs by country. For instance, 50% of Malaysia's FDI inflows concentrate on the manufacturing sectors while in contrast, in Singapore, the service sector accounts for nearly 60% on average.

3. Review of literature

Literature review suggests that the interrelationship between CO_2 emissions, economic growth, FDI and energy consumption can be broadly classified into three separate streams. First, empirical work focusing on testing the EKC hypothesis. Second, the analyses focusing on the energy-CO_2 emissions nexus and third, the analyses on the pollution haven hypotheses linking either trade liberalisation or FDI on CO_2 emissions. Nevertheless, for the ASEAN countries, limited numbers of studies are available and Table 2 summarises some of the major findings.

In examining the EKC hypothesis using panel co-integration, based on pooled sample results, Lean and Smyth [12] concluded that as a whole, there seems to be evidence supporting the EKC hypothesis in ASEAN-5. However, when examining the individual country's results, the relationship between economic growth and CO_2 emissions is mixed. Except for the Philippines, they found no support of EKC in Malaysia, Singapore and Thailand. In the case of Indonesia, income seems to increase monotonically with CO_2 emissions. The panel Granger causality test suggests that there is no causal relationship running from income to CO_2 emission in the short and long run as a whole. Nevertheless, only in the long run, causality runs from CO_2 emission to income. However, individual country's causality test is not available.

A recent study by Narayan and Narayan [14] compared the long-run and short-run income elasticity to gauge the EKC hypothesis in 43 developing countries.[7] Narayan and Narayan [14] argued that in none of the countries (Indonesia, Malaysia, the Philippines and Thailand) is the EKC hypothesis supported. However, based on the error correction term (ECT), except for the Philippines, income significantly affects CO_2 emission at 10% or better in the long run. This implies that a long-run relationship exists between income and CO_2 emissions. As a whole, while the income-CO_2 emission nexus is supported, the EKC is not supported in ASEAN especially Indonesia, Malaysia and Thailand. The only dissimilarity in results between Lean and Smyth [12] and Narayan and Narayan [14] is the evidence of the EKC hypothesis with respect to the Philippines where the results of Lean and Smyth [12] showed support for EKC in the Philippines. In addition, Lean and Smyth [12] only found long-run income effects on CO_2 emissions in the Philippines and Indonesia. However, in these studies, while the time frame is sufficient for pooled panel data analysis, it may not be sufficient for individual country analysis. This might explain why only in the case of the pooled sample is the EKC supported [12] and not for the individual countries except for the Philippines. Therefore, this may warrant re-examination and validity of the EKC hypothesis in ASEAN-5. Some of the contrasting results require validation, in which our study aims to provide. With regards to energy consumption and CO_2 nexus, Lean and Smyth [12] found significant long-run impact in all the 5 countries. The panel Granger causality indicates that causality runs from CO_2 to energy consumption only in the short run.

Niu et al. [35] investigated the long-run relationship between energy consumption, GDP and CO_2 for eight Asia-Pacific countries

[4] Although the vehicle price is high in relation to other counterparts like Thailand, Indonesia and the Philippines, the total cost of vehicle ownership in Malaysia is still cheaper due to mainly subsidised fuel price, lower road tax and insurance premiums. Among the cities, vehicle ownership per 100 persons is highest in Bangkok, Kuala Lumpur and Jakarta.

[5] Two of these studies only used Japanese FDI while Letchumanan and Kodama [31] used simple correlation analysis between FDI and pollution intensity to analyse the link.

[6] Includes Brunei, Cambodia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam and Indonesia. Authors' calculation based on UNCTAD Foreign Direct Investment database.

[7] EKC is supported, if the long-run income elasticity is smaller than the short run.

Table 2
Summary of selected literatures and major findings.

Authors	Variables	Methodology	Countries	Cointegration (panel)	EKC	GDP effects on CO_2 (LR)	Granger causality (panel)	Energy effects on CO_2 (LR)	Granger causality (panel)	FDI effects on CO_2 (LR)
Narayan and Narayan [14]	GDP, CO_2	Pedroni cointegration	Malaysia	Yes	No	Yes (1.12)	–	–	–	–
			Indonesia		No	Yes (1.22)				
			Philippines		No	Yes (1.73))				
			Thailand		No	Yes (1.52				
Lean and Smyth [12]	GDP, CO_2, E	Johansen Fisher panel cointegration test, panel DOLS	Malaysia	Yes	No	No (−0.562)	LR: $CO_2 \rightarrow$ GDP SR: $CO_2 \times$ GDP	Yes (0.724)	LR: E $\times CO_2$	–
			Indonesia		No	Yes (5.122)		Yes (0.387)	SR: $CO_2 \rightarrow$ E	
			Philippines		Yes	Yes (8.062)		Yes (0.308)		
			Thailand		No	No (2.153		Yes (0.511)		
			Singapor		No	No (0.753)		Yes (0.424)		
Niu et al. [35]	GDP, CO_2, E	Pedroni cointegration	Thailand	Yes	–	Yes (2.08)	LR: $CO_2 \rightarrow$ GDP	Yes (3.44)	LR: E $\rightarrow CO_2$	–
			Indonesia			Yes (2.03)		Yes (3.11)	SR: E $\rightarrow CO_2$	
Hossain [15]	CO_2, GDP, U, O, E	Johansen Fisher panel cointegration test	Malaysia	Yes	–	No (0.116)	LR: $CO_2 \times$ GDP	No (0.190)	LR: E $\times CO_2$	–
			Thailand			Yes (0.811)	SR: GDP $\rightarrow CO_2$	Yes (0.742)	SR: E $\times CO_2$	
			Philippines			Yes (1.024)		Yes (0.531)		
Ang [6]	GDP, CO_2, E	Johansen cointegration	Malaysia	Yes	–	–	LR: GDP $\rightarrow$ E LR: $CO_2 \rightarrow$ GDP	–	–	–
Atici [33]	CO_2, GDP, Export, FDI	Random and Fixed Effect (Panel)	Malaysia	–	Yes	Yes	–	–	–	No
			Indonesia							
			Philippines							
			Thailand							
Merican et al. [36]	CO_2, GNI, MVA, FDI	ARDL	Malaysia	Yes	–	Yes (0.87)	–	–	–	Yes (0.57)
			Indonesia			No (0.39)				Yes (−4.93
			Philippines			No (−0.5)				Yes (2.5)
			Thailand			No (0.29)				Yes (2.4)
			Singapore			Yes (0.87)				No (−0.01)

SR = Short run; LR = Long run; E = Energy consumption; CO_2 = Carbon dioxide emission; GDP = Income; GNI = Gross National Income; O = Oil Consumption; MVA = Manufacturing value added; U = Unemployment. The arrows ($\rightarrow$ and $\leftrightarrow$) represent the direction of causality while $\times$ indicates no causality. Values in parenthesis ( ) is the long-run elasticities.

that included four developing countries, namely China, India, Thailand, and Indonesia using panel data techniques. For the developing countries there was a long-run relationship between energy consumption, coal, oil, and CO_2 emissions. Conversely, they could not find any long-run relationship between natural gas and electricity on CO_2 emissions. Similarly, the study concludes that the main cause of CO_2 emissions is energy consumption, especially in developing countries. The study also examines the individual countries by establishing individually-fixed varying coefficient model between per capita energy use and CO_2 emissions. For Thailand and Indonesia, the coefficient of energy consumption on CO_2 emissions is 3.44 and 3.11, respectively. Similarly, unlike the case of developed countries, the effect of per capita GDP on per capita CO_2 emissions is greater than unity, for instance, Thailand (2.08) and Indonesia (2.03). Both the coefficients of energy consumption and GDP on CO_2 emissions are relatively high for Thailand and Indonesia. Granger causality results for the developing countries show causality running from CO_2 emissions to GDP and energy consumption to CO_2 emissions in the long run. However, in the short run, they found evidence of unidirectional causality running from energy consumption to CO_2 emissions.

Hossain [15] examined the relationship between CO_2, energy consumption, economic growth, trade openness and urbanisation for a panel of nine newly-industrialised countries that included Malaysia, the Philippines and Thailand. The study indicates that income and energy consumption have a long-run significant impact on CO_2 emissions in the Philippines and Thailand but not for Malaysia. The panel Granger causality test indicates that there is no long-run causality between income, energy consumption and CO_2 emissions. However, in the short run, the causality runs from income to CO_2 emissions. Ang [6] examined the long-run relationship between GDP, CO_2 and energy consumption for Malaysia. The results indicate that CO_2 emissions and energy consumption are positively related to GDP in the long run. The long-run elasticity of GDP with respect to CO_2 emissions and energy consumption are found to be 0.238 and 0.548, respectively. The results of the Granger causality show that there is evidence of unidirectional causality running from GDP to energy consumption in the long run. Likewise, there is also a weak causality running from CO_2 emissions to economic growth in the long-run. However, the study did not test the EKC hypothesis or the impact of transport energy use and FDI on CO_2 emissions.

Literature examining the pollution haven hypothesis is very scarce in the case of ASEAN. Atici [33] examined the relationship between trade liberalisation and FDI on CO_2 emissions in ASEAN with specific reference to trade flow with Japan using both random and fixed effects panel analysis. The panel results show that FDI has a negative effect on CO_2 indicating that FDI benefits the ASEAN countries in reducing pollution as a whole. However, the results for the group of countries that included Indonesia, Malaysia, Thailand and the Philippines indicate that FDI does not have any significant impact on CO_2 emissions. The author suggested a further research with regards

to FDI due to the fact that FDI influence may differ among countries. For the developed ASEAN countries (Brunei and Singapore), FDI is found to have an easing impact on the environment. The results also indicate that trade liberalisation measures as export to GDP has an influence on the environment in ASEAN.[8] Similarly, a study by Elliott and Shimamoto [32] that examined Japanese FDI at sectoral level to Malaysia, Indonesia and the Philippines indicates that FDI has no impact on pollution in these countries. Merican et al. [36] assessed the impact of FDI on pollution in ASEAN-5. Using autoregressive distributed lag (ARDL) estimation, they found that FDI significantly contributes to pollution in Malaysia, Thailand, and the Philippines but not in the other two countries. The long-run estimated elasticity of FDI in Malaysia, Thailand and the Philippines are 0.57, 2.4 and 2.5, respectively.

It appears that there are some inconclusive and mixed evidences with regards to the complex relationship between CO_2 emissions, energy consumption, FDI and GDP. Indeed, evidence for the pollution haven hypothesis is limited. Similarly, the majority of the studies used panel data analysis, leaving less space for any comprehensive evidence on the long-run relationship and the causality between the variables at individual country level. For instance, knowing the long-run relationship between CO_2 emissions and GDP for specific countries allows policymakers to consider the option as to whether CO_2 reduction policies would work [37]. Similarly, the immediate short-run and long-run impact as well as the causal relationship will add additional insights on the complex relationship between the variables.

4. Model, econometric methods and data

4.1. Data sources and model specification

This study focuses on the relationship between per capita CO_2 emissions (CO_{2t}), per capita energy consumption for road transportation sector (EC_t), per capita real FDI, per capita real GDP (G_t) and the square of per capita real GDP (G_t^2) for five ASEAN founding economies, namely Indonesia, Malaysia, the Philippines, Singapore and Thailand. This study uses the annual data from 1971 to 2008 extracted from *World Development Indicators* (WDI) database. The GDP deflator (2000=100) is used to compute the real GDP and real FDI variables for each ASEAN-5 economies. All variables are transformed into the natural logarithm form to induce immobility in the variance-covariance matrix (see [38,39]). The EKC hypothesis notes that the relationship between carbon dioxide emissions and income should be a non-linear quadratic form. Moreover, the earlier empirical studies as discussed in Section 3 showed that energy consumption, FDI and GDP are important determinants of CO_2 emissions. Following this arguments, to analyse the relationship between carbon dioxide and its determinants for ASEAN-5 economies[9], we employed the following model specification.

$$CO_{2t} = \pi_0 + \pi_1 EC_t + \pi_2 FDI_t + \pi_3 G_t + \pi_4 G_t^2 + \varepsilon_t \quad (1)$$

here, CO_{2t} is the per capita carbon dioxide emissions, EC_t is the per capita energy consumption for road transportation sector, G_t is the per capita real GDP (measured in US currency), and G_t^2 is the square of per capita real GDP (measured in US currency). The residuals ε_t are assumed to be normally distributed and white noise. The long-run parameters for CO_2 emissions with respect to energy consumption, real income, and square of real income are π_1, π_2, π_3 and π_4, respectively. The expected sign for π_1 is positive, while π_2 can be either positive or negative. According to EKC hypothesis, the sign for π_3 should be positive and π_4 should be negative.

4.2. Multivariate cointegration analysis

This study employs the multivariate cointegration test developed by Johansen [40] and Johansen and Juselius [41] to examine the existence of long-run equilibrium relationship. Gonzalo [42] performed a simulation study to compare the performance of five cointegration tests. Chronologically, the cointegration tests under investigation are ordinary least squares (OLS) residuals-based (Engle and Granger [43]), non-linear least squares (Stock [44]), principle components approach (Stock and Watson [45]), canonical correlations (Bossaerts [46]), and fully maximum likelihood error-correction model (Johansen [40]). The author found that Johansen's approach performs better than other cointegration tests even when errors terms are not normally distributed. Moreover, according to Masih and Masih [47], there are several advantages of using the Johansen–Juselius cointegration approach compared to the standard Engle–Granger residuals-based cointegration test. First, the Johansen–Juselius approach assumes that all the variables are endogenous, thus it does not face the problem in determining the dependent variable. Second, unlike the Engle–Granger approach, it can determine more than one cointegrating relationships. The Johansen–Juselius approach tests the presence of cointegrating relationships within the vector error-correction model (VECM) as follows:

$$\Delta W_t = \delta_0 + \delta_1 t + \Pi W_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta W_{t-i} + \varepsilon_t \quad (2)$$

whereby Δ is the change operator. The $(n \times 1)$ vector W_t is the endogenous variable CO_{2t}, EC_t, G_t and G_t^2. δ_0 and δ_1 are the parameters for the deterministic term, such as intercept and time trends (t) variables. The residuals ε_t are assumed to be spherically distributed and white noise. The matrix Π contains the long-run relationship information among the variables in W_t vector. If the variables in W_t are the integration of order one, $I(1)$ the cointegrating rank, r, is given the rank of $\Pi = \alpha\beta'$ where α is the matrix of parameters which represents the speed of convergence to the long-run equilibrium and β is the matrix of the cointegrating vector.

4.3. Granger causality analysis

If the Johansen cointegration test shows that the variables are co-integrated; the Granger causality test is performed within the VECM framework (see [48]) to avoid missing the long-run causality information.

$$\Delta CO_{2t} = \phi_0 + \sum_{i=1}^{p} \phi_{1i} \Delta CO_{2t-i} + \sum_{i=0}^{p} \phi_{2i} \Delta EC_{t-i} + \sum_{i=0}^{p} \phi_{3i} \Delta FDI_{t-i} + \sum_{i=0}^{p} \phi_{4i} \Delta G_{t-i} + \sum_{i=0}^{p} \phi_{5i} \Delta G_{t-i}^2 + \rho_1 \varepsilon_{t-1} + \upsilon_{1t} \quad (3)$$

$$\Delta EC_t = \varphi_0 + \sum_{i=0}^{p} \varphi_{1i} \Delta CO_{2t-i} + \sum_{i=1}^{p} \varphi_{2i} \Delta EC_{t-i} + \sum_{i=0}^{p} \varphi_{3i} \Delta FDI_{t-i} + \sum_{i=0}^{p} \varphi_{4i} \Delta G_{t-i} + \sum_{i=0}^{p} \varphi_{5i} \Delta G_{t-i}^2 + \rho_2 \varepsilon_{t-1} + \upsilon_{2t} \quad (4)$$

[8] This is based on a panel analysis that includes Indonesia, Thailand, Malaysia and the Philippines.

[9] The theoretical justification on the links between income, FDI, energy consumption and CO_2 emission is well justified in the literature see [1,6,12,14,15]. This paper adopts the same approach and model specification.

Table 3
The results of DF-GLS unit root test.

Variables	ASEAN economies				
	Indonesia	Malaysia	Philippines	Singapore	Thailand
CO_{2t}	−2.815 (1)	−2.370 (0)	−1.661 (0)	−1.509 (0)	−1.823 (1)
ΔCO_{2t}	−5.793 (1)***	−7.065 (0)***	−6.080 (0)***	−5.491 (1)***	−3.666 (0)**
$\Delta\Delta CO_{2t}$	−4.892 (3)***	−6.049 (1)***	−8.699 (0)***	−6.152 (1)***	−7.347 (0)***
EC_t	−2.157 (1)	−2.215 (0)	−2.063 (3)	−1.444 (0)	−1.532 (1)
ΔEC_t	−4.480 (0)***	−6.945 (0)***	−5.112 (0)***	−7.995 (0)***	−4.606 (0)***
$\Delta\Delta EC_t$	−6.857 (1)***	−6.329 (1)***	−7.147 (0)***	−12.780 (0)***	−8.449 (0)***
FDI_t	−2.464 (2)	−2.393 (1)	−4.342 (0)***	−2.735 (3)	−3.146 (0)
ΔFDI_t	−6.076 (2)***	−8.179 (0)***	−8.262 (0)***	−5.963 (0)***	−6.350 (0)***
$\Delta\Delta FDI_t$	−7.899 (2)***	−8.621 (1)***	−9.491 (1)***	−8.358 (0)***	−7.224 (1)***
G_t	−1.910 (1)	−1.967 (0)	−2.292 (1)	−1.320 (0)	−2.091 (1)
ΔG_t	−4.588 (0)***	−5.181 (0)***	−3.771 (1)***	−4.890 (0)***	−3.448 (0)**
$\Delta\Delta G_t$	−6.461 (1)***	−7.601 (1)***	−5.572 (1)***	−7.146 (1)***	−6.215 (0)***
G_t^2	−2.154 (1)	−2.834 (3)	−2.274 (1)	−1.614 (0)	−2.262 (1)
ΔG_t^2	−4.566 (0)***	−5.209 (0)***	−3.762 (1)**	−4.955 (0)***	−3.435 (0)**
$\Delta\Delta G_t^2$	−6.435 (1)***	−7.675 (1)***	−5.580 (1)***	−7.092 (1)***	−5.478 (1)***

Note: The asterisks *** and ** denotes the significance level at 1 and 5%, respectively. Δ is the first difference operator, while ΔΔ is the second difference operator. The lag order for DF-GLS test is set by Akaike information criterion (AIC). Figure in parentheses denotes the optimal lag order. The critical values are obtained from Elliot et al. [70].

$$\Delta FDI_t = \vartheta_0 + \sum_{i=0}^{p} \vartheta_{1i}\Delta CO_{2t-i} + \sum_{i=0}^{p} \vartheta_{2i}\Delta EC_{t-i} + \sum_{i=1}^{p} \vartheta_{3i}\Delta FDI_{t-i} + \sum_{i=0}^{p} \vartheta_{4i}\Delta G_{t-i} + \sum_{i=0}^{p} \vartheta_{5i}\Delta G_{t-i}^2 + \rho_3\varepsilon_{t-1} + \upsilon_{3t} \tag{5}$$

$$\Delta G_t = \theta_0 + \sum_{i=0}^{p} \theta_{1i}\Delta CO_{2t-i} + \sum_{i=0}^{p} \theta_{2i}\Delta EC_{t-i} + \sum_{i=0}^{p} \theta_{3i}\Delta FDI_{t-i} + \sum_{i=1}^{p} \theta_{4i}\Delta G_{t-i} + \sum_{i=0}^{p} \theta_{5i}\Delta G_{t-i}^2 + \rho_4\varepsilon_{t-1} + \upsilon_{4t} \tag{6}$$

$$\Delta G_t^2 = \psi_0 + \sum_{i=0}^{p} \psi_{1i}\Delta CO_{2t-i} + \sum_{i=0}^{p} \psi_{2i}\Delta EC_{t-i} + \sum_{i=0}^{p} \psi_{3i}\Delta FDI_{t-i} + \sum_{i=0}^{p} \psi_{4i}\Delta G_{t-i} + \sum_{i=1}^{p} \psi_{5i}\Delta G_{t-i}^2 + \rho_5\varepsilon_{t-1} + \upsilon_{5t} \tag{7}$$

here, Δ is the first difference operator and p is the optimal lag structure. The residuals (υ_{1t},υ_{2t},υ_{3t},υ_{4t},υ_{5t}) are assumed to be serially independent with zero mean and finite covariance matrix. ε_{t-1} is the one period lagged error-correction term derived from the cointegrating vector. If the variables are not co-integrated, the Granger causality tests will be conducted with stationary variables in the vector autoregression (VAR) system. With the above VECM specification, we can ascertain the short and long-run Granger causality. From Eq. (3), $\phi_{4i} \neq \phi_{5i} \neq 0 \forall_p$ implies economic growth Granger-cause pollution in the short run. To test the null hypothesis that pollution does not Granger-cause economic growth, we estimate Eqs. (6) and (7) and test the significance of $\theta_{1i}=\psi_{1i}=0$ using the Wald test. Rejection of the null hypothesis indicates pollution Granger-cause economic growth in the short run. On the other hand, $\theta_{1i}\neq\psi_{1i}\neq\rho_4\neq\rho_5\neq0$, implies pollution Granger-cause economic growth in the long run. Similar testing procedure is applied to test the Granger causality among other variables in the system.

Table 4
The results of cointegration test.

Panel A: Johansen cointegration test					
Tests		Indonesia	Malaysia	Singapore	Thailand
H_0	H_1	$k=1, r=1$	$k=2, r=2$	$k=1, r=0$	$k=1, r=1$
		Adjusted-*LR* (λtrace)			
$r=0$	$r\geq1$	68.5914**	67.9808*	54.4045	67.1443*
$r\leq1$	$r\geq2$	42.3131	46.3942*	33.4245	37.5396
$r\leq2$	$r\geq3$	23.0772	25.9629	18.2129	20.8604
$r\leq3$	$r\geq4$	8.2431	9.4861	7.3208	7.3706
$r\leq4$	$r\geq5$	0.8425	2.0130	0.3697	0.3668
Panel B: Cointegrating equations					
CO_{2t}		1.0000	1.0000	–	1.0000
EC_t		0.5012***	0.3708**	–	0.6424***
FDI_t		−0.0034	0.0085	–	0.0056
G_t		2.2198*	−3.1602**	–	−1.8505**
G_t^2		−0.1329	0.2901***	–	0.1766***
Constant		−7.3225*	8.8737*	–	5.9312*

Note: The asterisks ***, ** and * denotes significance at the 1, 5 and 10% levels, respectively. The critical values for Johansen cointegration test are obtained from MacKinnon et al. [71]. The system-wise AIC is used to determine the optimal lag for Johansen cointegration test.

5. Empirical results

5.1. Unit root results

In the time series analysis, testing for the degree of integration is a must because regression results may be spurious if the variables are non-stationary and/or non-cointegrated. Given the small sample of this study, we perform the Dickey–Fuller Generalised Least Square (DF-GLS) unit root test to examine the order of integration of each series. The DF-GLS test results are reported in Table 3.

At the second order of difference (ΔΔ), the DF-GLS results suggest that all variables are stationary at the 1% significance level. Similarly, the variables are also stationary at the first difference (Δ). Finally, we found that all variables become non-stationary when the variables are in the level, except for per capita real FDI for the Philippines. With these findings, we can conclude that CO_{2t}, EC_t, G_t and G_t^2 are strongly $I(1)$ in all ASEAN-5 economies. FDI_t is found to be $I(1)$ in Indonesia, Malaysia, Singapore and Thailand, but it is an $I(0)$ variable in the Philippines. Therefore, we perform the Johansen cointegration test to examine the presence of a long-run equilibrium relationship among CO_{2t}, EC_t, FDI_t, G_t and G_t^2 only for Indonesia, Malaysia, Singapore and Thailand.

5.2. Cointegration test results

In performing the Johansen cointegration test, scholars should consider three important issues. The first issue is the choice of

Table 5
The results of causality tests.

Null hypotheses	Short-run Granger causality test					Long-run Granger causality test		
	Indonesia χ^2-statistics	Malaysia	Philippines	Singapore	Thailand	Indonesia χ^2-statistics	Malaysia	Thailand
$\Delta CO_{2t} \nrightarrow \Delta EC_t$	5.592**	10.265**	32.705***	2.816	13.577***	5.699*	12.060**	13.599***
$\Delta CO_{2t} \nrightarrow \Delta FDI_t$	1.468	2.470	0.154	1.339	0.149	12.687***	3.338	1.356
$\Delta CO_{2t} \nrightarrow \Delta G_t$, ΔG_t^2	4.325	5.512	12.786**	20.710***	0.832	18.818***	6.347	20.222***
$\Delta EC_t \nrightarrow \Delta CO_{2t}$	4.290	0.393	23.959***	0.154	10.257***	18.130***	13.645***	21.275***
$\Delta EC_t \nrightarrow \Delta FDI_t$	9.858**	1.204	0.375	0.211	0.060	18.115***	1.252	0.580
$\Delta EC_t \nrightarrow \Delta G_t$, ΔG_t^2	18.702***	14.828***	1.221	24.320***	6.595	18.082***	11.476**	21.771***
$\Delta FDI_t \nrightarrow \Delta CO_{2t}$	0.005	0.029	11.246**	8.274**	4.866*	15.004***	13.124***	13.565***
$\Delta FDI_t \nrightarrow \Delta EC_t$	0.440	0.058	2.562	0.159	0.074	1.156	3.067	1.790
$\Delta FDI_t \nrightarrow \Delta G_t$, ΔG_t^2	33.593***	18.508***	6.730	10.649**	1.946	33.375***	15.169***	20.227***
ΔG_t, $\Delta G_t^2 \nrightarrow \Delta CO_{2t}$	8.988**	22.074***	0.351	10.310**	14.835***	20.695***	28.962***	20.725***
ΔG_t, $\Delta G_t^2 \nrightarrow \Delta EC_t$	5.815	10.426**	25.077***	5.878*	2.656	8.117	15.575***	5.327
ΔG_t, $\Delta G_t^2 \nrightarrow \Delta FDI_t$	34.269***	20.043***	5.517	17.557***	0.708	36.593***	24.590***	1.684

Note: The asterisks *** and ** denote statistical significance at the 1 and 5%, respectively.

appropriate lag length. Too many lags may over consume the degree of freedom, while too few lags may weaken the dynamism properties. Hence, we apply the system-wise AIC statistic to select an optimal lag length. The second issue is the choice of deterministic components (i.e. constant and trend). Johansen [49] noted that the asymptotic distributions of the LR tests for cointegration are very sensitive to the choice of deterministic components. With respect to this, Johansen [50] suggested the use of Pantula's [51] principle to select a proper model. The third issue is that the Johansen cointegration test would over-reject the null hypothesis of no cointegration when the sample size is small [52]. To mitigate this problem, we follow the recommendation of Reinsel and Ahn [53] by adjusting the standard LR statistics for small samples with the scale factor of $(T-pk)/T$, where T is the sample size, p is the number of endogenous variables and k is the optimal lag length.

The results of the Johansen cointegration test together with the optimal lag structure (k) and cointegrating ranks (r) are presented in Panel A of Table 4. The adjusted trace statistics for a small sample suggest that the variables are cointegrated in Indonesia, at a 5% significant level, while in Malaysia and Thailand it is significant at the 10% level. However, for the case of Singapore, we fail to find any evidence of cointegration. In other words, we can only find a meaningful long-run equilibrium relationship between CO_{2t} and its determinants in Indonesia, Malaysia and Thailand. Given that the variables are cointegrated, we estimate the long-run relationship between CO_2 emissions, road transport energy consumption, FDI, GDP and square of GDP using the Ordinary Least Squares (OLS) estimator.[10] The long-run elasticity is reported in Panel B of Table 4. Interestingly, the long-run elasticity of CO_2 emissions with respect to road transport energy consumption implies that a 1% increase in per capita transport energy consumption on average increases the per capita CO_2 emissions by 0.5012% (for Indonesia), 0.3708% (for Malaysia) and 0.6424% (for Thailand). The results are consistent with the existing studies that used total energy consumption (e.g. [6,7]). Likewise, the effect of FDI on CO_2 emission is insignificant and small for Indonesia, Malaysia and Thailand. The elasticity of FDI ranges from −0.0034 to 0.0085. Regardless of the significant level, we find that the impact of road transport energy consumption on CO_2 is larger than FDI in all the three countries, suggesting that reduced road energy consumption would be more effective to reduce CO_2 emissions.

From our estimation results in Panel B of Table 4, we find that for none of the selected ASEAN economies, the conventional EKC hypothesis is supported. For the case of Indonesia, we find that G_t has a significant positive effect on CO_2 emissions, while G_t^2 is statistically insignificant even at the 10% level. Thus, the relationship between CO_2 emission and income in Indonesia tend to be linear. Apart from that, we find a significant non-linear relationship between CO_2 emissions and income in Malaysia and Thailand. Instead of an inverted U-shaped relationship, the results of our study reveal that the relationship between CO_2 emission and income in Malaysia and Thailand are more likely to be a normal U-shape curve. These results are in sharp contrast with the earlier empirical studies (e.g. [59–61]) and also do not support the conventional wisdom of EKC hypothesis (i.e. inverted U-shaped relationship). However, the findings of our study are consistent with the normal U-shape curve presented in Moomaw and Unruh [62], Ekins [63], Kaufmann et al. [64], List and Gallet [65] and Dinda et al. [66]. Given the fact that Indonesia, Malaysia and Thailand are developing countries, it is not surprising to reject the conventional EKC hypothesis because they may not have achieved a desired level of income to apprehend the inverted U-shape relationship stipulated by the EKC hypothesis. Our results are also consistent with Narayan and Narayan [14] and Lean and Smyth [12] in the case of Malaysia, Indonesia and Thailand.

5.3. Granger causality results

Since the Johansen cointegration test results indicate that CO_2 emissions and their determinants are only cointegrated in Indonesia, Malaysia and Thailand, we perform the Granger causality tests for these three ASEAN economies using the VECM framework. We implement the Granger causality test for the Philippines and Singapore with stationary variables in the VAR framework because there is no evidence of cointegration. Table 5 reports the results of Granger causality tests of the ASEAN-5 economies while Fig. 1 summarises the direction of causality.

In the long run, we find evidence of bi-directional causality between economic growth and CO_2 emission in Indonesia and Thailand, but for the case of Malaysia, the causality runs from economic growth to CO_2 emission rather than the opposite direction. In terms of energy-growth nexus, we find evidence of long-run bi-directional causality between transport energy consumption and economic growth only in Malaysia which is

[10] On the basis of Monte Carlo experiment, Abeysinghe and Tan [54] found that in a small sample, the performance of OLS estimator is superior to other long-run estimators proposed by Bardsen [55], Johansen and Juselius [41], Phillips and Hansen [56], Engle and Yoo [57], and Stock and Watson [58].

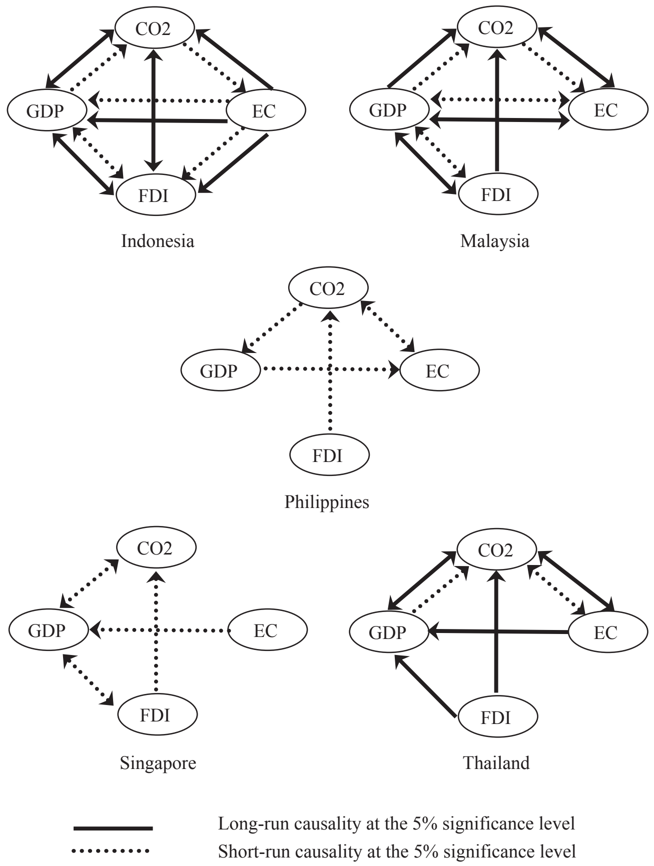

Fig. 1. Summary of the short and long run Granger causalities.

consistent with Tang [67,68] and Tang and Tan [69], while the causality direction changes uni-directionally from transport energy consumption to economic growth in Indonesia and Thailand. The FDI and economic growth Granger-cause each other (i.e. bi-directionally) in Malaysia and Indonesia. In Thailand, the causality is unidirectional from FDI to economic growth. Moreover, we found that there is also unidirectional causality running from FDI to CO_2 emission in Malaysia and Thailand, while the variables become bi-directional causality in Indonesia. FDI and energy consumption are neutral in Malaysia and Thailand, but we found that there is a long-run unidirectional causality running from energy consumption to FDI in Indonesia.

Turning to the short-run causal effect, the result reveals that there is an evidence of bi-directional causality between economic growth and CO_2 emissions in Singapore. Nevertheless, we found one-way causality from economic growth to CO_2 emissions in Indonesia, Malaysia and Thailand, but the opposite causality direction exists in the Philippines. Apart from that, we found that transport energy consumption Granger-causes economic growth in Indonesia, Malaysia and Singapore, but the reverse cause only exists in Malaysia whereby it corroborated with the finding of Tang and Tan [69]. For the Philippines, the short-run causality runs from economic growth to energy consumption. Furthermore, there is also evidence of bi-directional causal relationship between FDI and economic growth in Indonesia, Malaysia and Singapore. However, FDI and economic growth in the Philippines and Thailand do not Granger-cause each other. In the short run, we found that FDI Granger-cause CO_2 emissions only in the Philippines and Singapore. With the exception of Indonesia, the causality between FDI and transport energy consumption for the rest of the ASEAN economies under investigation tend to be neutral in the short run. From the above causality results, we could conclude that economic growth, transport energy consumption and FDI are important factors in determining the CO_2 emissions in three of the ASEAN economies in the long-run. With the exception of the Philippines, we observe that energy and FDI are the engines of growth for many ASEAN-5 economies either in the short and/or the long run. Hence, the energy-led growth hypothesis and the FDI-led growth hypothesis are valid at least in Indonesia, Malaysia, Singapore and Thailand.

6. Conclusions and policy recommendations

This study examines the dynamic linkages between CO_2 emissions, road transport energy consumption, FDI and economic growth. The results indicate that only in the case of Malaysia, Indonesia and Thailand, the variables are cointegrated. This suggests that there is a long-run relationship between the variables and CO_2 emissions and policy to achieve the targeted commitment of CO_2 in ASEAN especially in Malaysia, Thailand and Indonesia should take into account the issues of road energy consumption, types of FDI inflows[11] as well as economic growth. Relatively, economic growth and road transport energy consumption are found to extract higher influence on CO_2 emissions and policy options should pay more attention on this. Since growth extracts higher influence on CO_2 emissions, Indonesia, Malaysia and Thailand should focus on promoting an economic model based on sustainable development as their main agenda. Malaysia has committed to reduce carbon emissions by 40% by 2020 and its current efforts to move into a green economy should provide some lessons. Intensifying green economy initiatives will allow decoupling economic growth and CO_2 emissions. However, proper implementation plans are necessary for the success of such initiatives. ASEAN members, as a whole, should also share their individual experience on sustainable development practices.

In addition, promoting the use of more energy efficient vehicles or even hybrid vehicles as well as being selective in FDI strategies to control the pollution industries to relocate themselves are two important policy options that might reduce CO_2 emissions in these countries. Reducing the energy intensity of the transport sector may also require the government to promote and invest in public transport, develop clean technology, as well as establish regulatory-like emission standards and vehicle occupancy or encourage car pool to reduce congestions. New investment in road upgrading and maintenance are needed. Fuel subsidisation especially in Indonesia and Malaysia may need to be revamped. However, this should be done with care as it may deter economic growth. There is no long-term relationship in the case of Singapore for the following reasons. Despite Singapore being the main FDI destinations, the majority of the FDI inflows are targeted at the services sectors, mainly financial services, leaving less room for any significant influence on CO_2 emissions. Similarly, road transport energy consumption in Singapore is well below the level that could trigger any significant CO_2 emissions.

References

[1] Hatzigeorgiou E, Polatidis H, Haralambopoulos D. CO_2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977–2007. Applied Energy 2011;88:1377–85.

[11] Although long-run coefficient of FDI is not significant, we find evidence of causality running from FDI to CO_2 emissions. The causality results are preferred in policymaking because it considered both the dynamic and the interrelationship among the variables in the system.

[2] Wang SS, Zhou DQ, Zhou P, Wang QW. CO_2 emissions, energy consumption and economic growth in China: a panel data analysis. Energy Policy 2011;39:4870–5.
[3] Ghosh S. Examining carbon emissions economic growth nexus for India: a multivariate cointegration approach. Energy Policy 2010;38:3008–14.
[4] Ozturk I, Acaravci A. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics 2013;36:262–7.
[5] Zhang Y-J. The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 2011;39:2197–203.
[6] Ang JB. Economic development, pollutant emissions and energy consumption in Malaysia. Journal of Policy Modeling 2008;30:271–8.
[7] Acaravci A, Ozturk I. On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy 2010;35:5412–20.
[8] Chang C-C. A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. Applied Energy 2010;87:3533–7.
[9] Lee C-C, Lee J-D. Income and CO_2 emissions: evidence from panel unit root and cointegration tests. Energy Policy 2009;37:413–23.
[10] Bloch H, Rafiq S, Salim R. Coal consumption, CO_2 emission and economic growth in China: empirical evidence and policy responses. Energy Economics 2012;34:518–28.
[11] Zeng K, Eastin J. Do developing countries invest up? The environmental effects of foreign direct investment from less-developed countries World Development 2012;40:2221–33.
[12] Lean HH, Smyth R. CO_2 emissions, electricity consumption and output in ASEAN. Applied Energy 2010;87:1858–64.
[13] Ong HC, Mahlia TMI, Masjuki HH. A review on energy pattern and policy for transportation sector in Malaysia. Renewable and Sustainable Energy Reviews 2012;16:532–42.
[14] Narayan PK, Narayan S. Carbon dioxide emissions and economic growth: panel data evidence from developing countries. Energy Policy 2010;38:661–6.
[15] Hossain MS. Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 2011;39:6991–9.
[16] Solow RM. Applying growth theory across countries. World Bank Economic Review 2001;15:283–8.
[17] Athukorala P, Sen K. Saving, investment, and growth in India. Oxford: Oxford University Press; 2002.
[18] Deaton AS. Saving in developing countries: theory and review. In: Fisher S, de Tray D, editors. In: Proceedings of the World Bank Annual Conference on Development Economics. Washington DC: World Bank; 1989.
[19] Robertson D, Symons J. Some strange properties of panel data estimators. Journal of Applied Econometrics 1992;7:175-18.
[20] Pesaran MH, Smith R. Estimating long-run relationship from dynamic heterogeneous panels. Journal of Econometrics 1995;68:79–113.
[21] Chandran VGR, Sharma S, Madhavan K. Electricity consumption-growth nexus: the case of Malaysia. Energy Policy 2010;38:606–12.
[22] Pao H-T, Tsai C-M. Multivariate Granger causality between CO_2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. Energy 2011;36:685–93.
[23] Timilsina GR, Shrestha A. Transport sector CO_2 emissions growth in Asia: underlying factors and policy options. Energy Policy 2009;37:4523–39.
[24] EIA. International energy outlook 2011. Washington, DC: U.S. Energy Information Administration, U.S. Department of Energy; 2011.
[25] IEA. World energy outlook 2009. Paris: International Energy Agency; 2009.
[26] ASEAN. Fourth ASEAN state of the environment report 2009. Jarkata: ASEAN Secretariat; 2009.
[27] Dargay J, Gately D, Sommer M. Vehicle ownership and income growth, worldwide: 1960–2030. Energy Journal 2007;28:143–70.
[28] Cole MA. Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. Ecological Economics 2004;48:71–81.
[29] He J. Pollution haven hypothesis and environmental impacts of foreign direct investment: the case of industrial emission of sulfur dioxide (SO_2) in Chinese provinces. Ecological Economics 2006;60:228–45.
[30] Kearsley A, Riddel M. A further inquiry into the pollution haven hypothesis and the Environmental Kuznets Curve. Ecological Economics 2010;69:905–19.
[31] Letchumanan R, Kodama F. Reconciling the conflict between the 'pollution-haven' hypothesis and an emerging trajectory of international technology transfer. Research Policy 2000;29:59–79.
[32] Elliott RJR, Shimamoto K. Are ASEAN countries havens for Japanese pollution-intensive industry? World Economy 2008;31:236–54.
[33] Atici C. Carbon emissions, trade liberalization, and the Japan–ASEAN interaction: a group-wise examination. Journal of the Japanese and International Economies 2012;26:167–78.
[34] Karki SK, Mann MD, Salehfar H. Energy and environment in the ASEAN: challenges and opportunities. Energy Policy 2005;33:499–509.
[35] Niu S, Ding Y, Niu Y, Li Y, Luo G. Economic growth, energy conservation and emissions reduction: a comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Policy 2011;39:2121–31.
[36] Merican Y, Yusop Z, Noor ZM, Law SH. Foreign direct investment and the pollution in five ASEAN nations. International Journal of Economics and Management 2007;1:245–61.
[37] Wang K-M. Modelling the nonlinear relationship between CO_2 emissions from oil and economic growth. Economic Modelling 2012;29:1537–47.
[38] Chang T, Fang W, Wen LF. Energy consumption, employment, output and temporal causality: evidence from Taiwan based on cointegration and error-correction modelling techniques. Applied Economics 2001;33:1045–56.
[39] Fatai K, Oxley L, Scrimgeour FG. Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, the Philippines and Thailand. Mathematics and Computers in Simulation 2004;64:431–45.
[40] Johansen S. Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control 1988;12:231–54.
[41] Johansen S, Juselius K. Maximum likelihood estimation and inference on cointegration with—applications to the demand for money. Oxford Bulletin of Economics and Statistics 1990;52:169–210.
[42] Gonzalo J. Five alternative methods of estimating long-run equilibrium relationships. Journal of Econometrics 1994;60:203–33.
[43] Engle RF, Granger CWJ. Co-Integration and error correction: representation, estimation, and testing. Econometrica 1987;55:251–76.
[44] Stock JH. Asymptotic properties of least squares estimators of cointegrating vectors. Econometrica 1987;55:1035–56.
[45] Stock JH, Watson MW. Testing for common trends. Journal of the American Statistical Association 1988;83:1097–107.
[46] Bossaerts P. Common nonstationary components of asset prices. Journal of Economic Dynamics and Control 1988;12:347–64.
[47] Masih AMM, Masih R. Are Asian stock market fluctuations due mainly to intra-regional contagion effects? Evidence based on Asian emerging stock markets Pacific-Basin Finance Journal 1999;7:251–82.
[48] Granger CWJ. Some recent development in a concept of causality. Journal of Econometrics 1988;39:199–211.
[49] Johansen S. Likelihood-based inference in cointegrated vector auto-regressive models. Oxford: Oxford University Press; 1995.
[50] Johansen S. Determination of cointegration rank in the presence of a linear trend. Oxford Bulletin of Economics and Statistics 1992;54:383–97.
[51] Pantula SG. Testing for unit roots in time series data. Econometric Theory 1989;5:256–71.
[52] Cheung YW, Lai KS. Finite-sample sizes of Johansen's likelihood ratio tests for cointegration. Oxford Bulletin of Economics and Statistics 1993;55:313–28.
[53] Reinsel GC, Ahn SK. Vector autoregressive models with unit roots and reduced rank structure: estimation, likelihood ratio test and forecasting. Journal of Time Series Analysis 1992;13:353–75.
[54] Abeysinghe T, Tan KB. Small sample estimation of a cointegrating vector: an empirical evaluation of six estimation techniques. Applied Economics 1999;6:645–8.
[55] Bardsen G. Estimation of long run coefficients in error correction models. Oxford Bulletin of Economics & Statistics 1989;51:345–50.
[56] Phillips PCB, Hansen BE. Statistical inference in instrumental variable regression with $I(1)$ processes. Review of Economic Studies 1990;57:99–125.
[57] Engle RF, Yoo BS. Cointegrated economic time series: an overview with new result. In: Engle RF, Granger CWJ, editors. Long run economic relationship: readings in cointegration. New York: Oxford University Press; 1991.
[58] Stock JH, Watson MW. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica 1993;61:783–820.
[59] Ang JB. CO_2 emissions, energy consumption, and output in France. Energy Policy 2007;35:4772–8.
[60] Halicioglu F. An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 2009;37:1156–64.
[61] Apergis N, Payne JE. CO_2 emissions, energy usage, and output in Central America. Energy Policy 2009;37:3282–6.
[62] Moomaw WR, Unruh GC. Are environmental Kuznets curves misleading us? The case of CO_2 emissions Environment and Development Economics 1997;2:451–63.
[63] Ekins P. The Kuznets curve for the environment and economic growth: examining the evidence. Environment and Planning A 1997;29:805–30.
[64] Kaufmann RK, Davidsdottir B, Garnham S, Pauly P. The determinants of atmospheric SO_2 concentrations: reconsidering the environmental Kuznets curve. Ecological Economics 1998;25:209–20.
[65] List JA, Gallet CA. The environmental Kuznets curve: does one size fit all? Ecological Economics 1999;31:409–23.
[66] Dinda S, Coondoo D, Pal M. Air quality and economic growth: an empirical study. Ecological Economics 2000;34:409–23.
[67] Tang CF. A re-examination of the relationship between electricity consumption and economic growth in Malaysia. Energy Policy 2008;36:3077–85.
[68] Tang CF. Electricity consumption, income, foreign direct investment, and population in Malaysia: new evidence from multivariate framework analysis. Journal of Economic Studies 2009;36:371–82.
[69] Tang CF, Tan BW. The linkages among energy consumption, economic growth, relative price, foreign direct investment, and financial development in Malaysia. Quality & Quantity 2012:1–17, http://dx.doi.org/10.1007/s11135-012-9802-4.
[70] Elliott G, Rothenberg TJ, Stock JH. Efficient tests for an autoregressive unit root. Econometrica 1996;64:813–36.
[71] MacKinnon JG, Haug AA, Michelis L. Numerical distribution functions of likelihood ratio tests for cointegration. Journal of Applied Econometrics 1999;14:563–77.